Landsat Science Team

Landsat Operations Report

13 January 2016

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U.S. Department of the Interior
U.S. Geological Survey

Agenda

- Mission Status (L7,L8)
- Archive Status
- LGAC Status
- Product Distribution
- L7/L8 Acquisition Status

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Landsat 7 Observatory Status – No Change

~ 16 years of on-orbit operations

Attitude Control Subsystem

- 05/05/2004 Gyro 3 Shut Off
- 1-gyro control system in development

Enhanced Thematic Mapper +

- 5/31/2003 SLC Failure
- 4/01/2007 Bumper mode

RF Comm Subsystem

X-band System

Performance nominal

S-band System

Performance nominal

Electrical Power Subsystem

Batteries

Performance nominal

Power Control Unit

- 10/18/2014 BVR failover

Solar Array

- 5/14/2002 Circuit #14 Failure
- 5/16/2005 Circuit # 6 Failure
- 8/13/2008 Circuit #14 partial recovery
- 14 circuits remain operating
- no impact to ops

Reaction Control System

- 1/07/04 Fuel line #4 thermostat #1a failure
- 2/24/05 Fuel line #4 thermostat failure; Primary heater circuit disabled
- 4/25/13 Fuel line #2 thermostat failure; Redundant heater circuit disabled

Command and Data Handling Subsystem

Solid State Recorder

- 11/15/1999 SSR PWA #23 Loss
- 02/11/2001 SSR PWA #12 Loss
- 12/07/2005 SSR PWA #02 Loss
- 08/02/2006 SSR PWA #13 Loss
- 03/28/2008 SSR PWA #22 Loss
- 09/03/2008 SSR PWA #23 Recovered
- 10/12/2013 SSR PWA #11 Loss
- Each PWA is 4% loss of launch capacity
- Boards are likely recoverable

Remote Tlm Cmd (RTC) Box

- 09/27/2014 RTC A Failover

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ETM+ 105% Duty Cycle Assessment

- **The Landsat 7 FOT completed its analysis of the effects of relaxing duty constraints on the ETM+ by up to 5%**
- **The test was conducted in two phases**
  - **Duty cycle constraints were relaxed by 2.5% for one 16-day period (August)**
  - **Relaxed by another 2.5% for an additional 6 week period (September-October)**
  - **Duty cycle constraint set back to 100% on October 31**
- **During the testing the Landsat 7 FOT engineers closely monitored the ETM+ Power Supply Heat Sink Temperatures and for any other changes**
- **Assessment did not uncover any effect on the ETM+ health and safety from the elevated duty cycle numbers during the test duration**
- **ETM+ 105% duty cycle has been approved and will begin no later than March 2016**
  - **Support Northern Hemisphere growing season and increased acquisitions over African Continent and Central America**

USGS

Mission Extension Options

- **Baseline: Place Landsat 7 in a disposable orbit approximately 20 Km below 705 Km**
  - **EOL estimate very early 2020**

- **Alternative: Place Landsat 7 in a disposable orbit approximately 4 Km below 705 Km**
  - **Fuel savings place EOL estimate to early 2021**
  - **Allows for potential limited overlap with Landsat 9**

- **USGS will make a determination on potential Landsat 7 extension options no later than December 2016**

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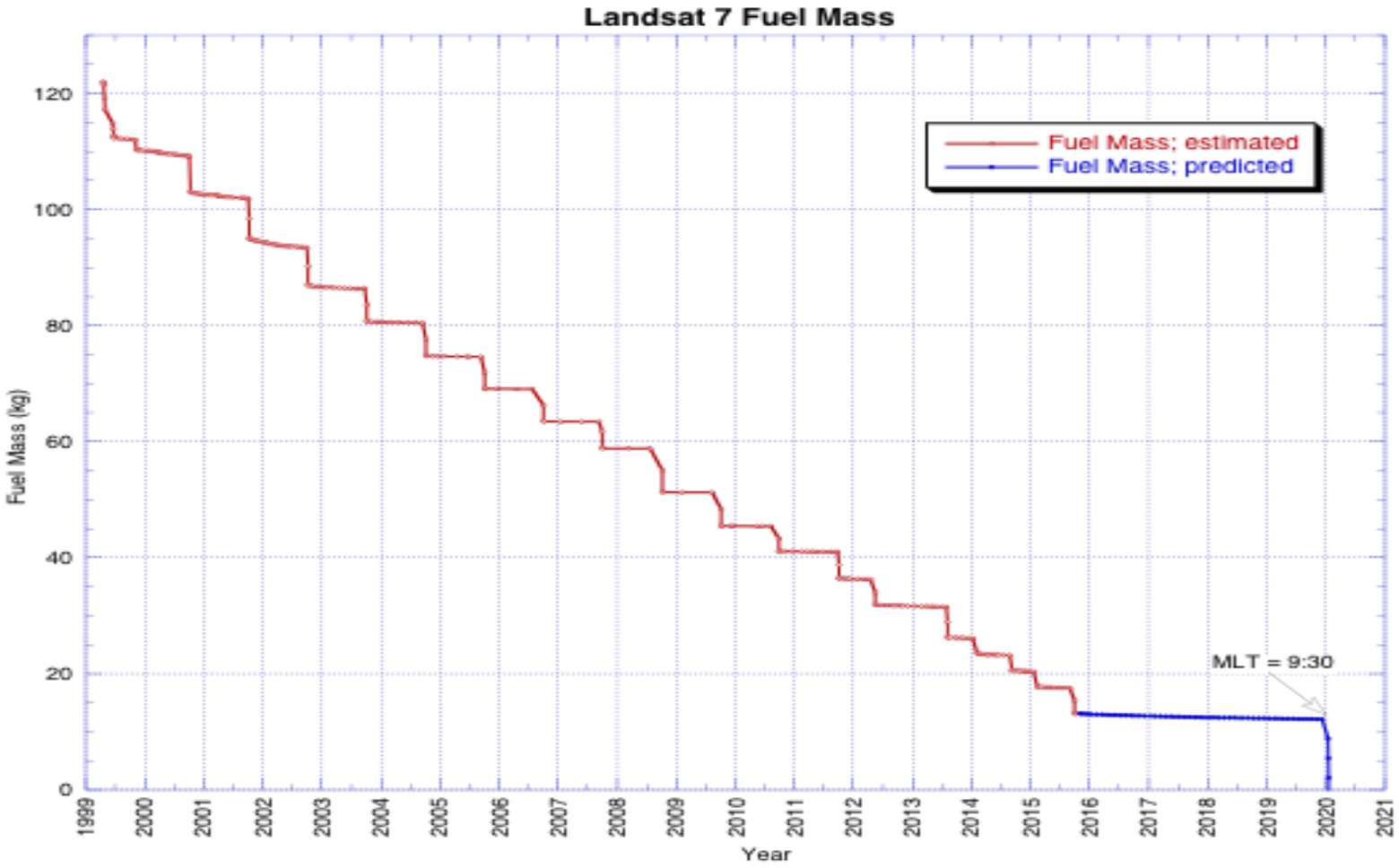
L7 Fuel Estimates



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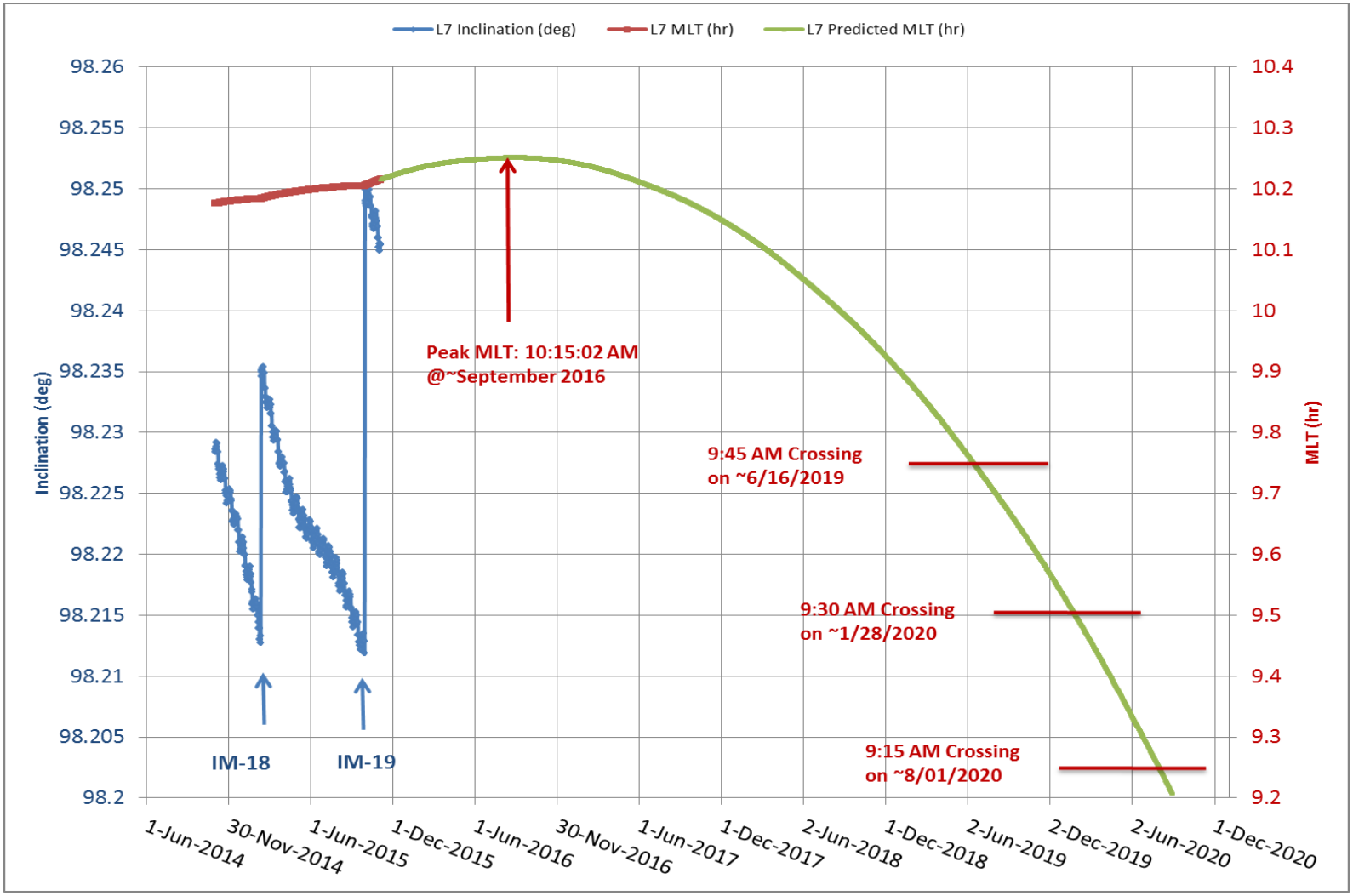
L7 Baseline MLT Long-Term Prediction



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Updated - Landsat 8 Observatory Status

~2 years 4 months of on-orbit operations

RF Communications
S-band System
X-band System

Operational Land Imager

Thermal Control System

Propulsion Subsystem

Attitude Control System

Electrical Power System
Batteries
Solar array

Thermal Infrared Sensor

October 2014 - Side-A SSM Encoder
September 2015 – Encoder Side-B current fluctuations

Command & Data Handling System

Solid State Recorder – File Delete (ghost file) errors
- Successfully corrected in September 2015

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TIRS B-side Encoder Current

- **Initial symptoms observed on TIRS B-side are comparable to the TIRS A side encoder current anomaly**
  - **TIRS A-side encoder electronics exhibited a runaway current after prolonged use**
  - **Reasonable to assume TIRS B-side will follow the same progression if unchecked**
  - **Consensus opinion that prolonged encoder use under these conditions will eventually result in encoder damage and potential loss of encoder electronics**

- **November 2, 2015: TIRS bands disabled in science data**
  - **Further understand problem; derive alternative operations concept**

- **Alternative operations concept defined**
  - **Objective is to minimize further damage to the TIRS instrument while emphasizing continuity and quality of measurements, along with long-term availability of TIRS**
  - **Approach minimizes the amount of time current is flowing to the encoder while maintaining ability to use the TIRS scene select mirror for calibration on a less periodic basis**
  - **Concept tested fully between November 13 and December 17**
  - **Modifications to DPAS will also be required in order to adjust to the change in frequency of calibration data**
    - **DPAS readiness projected as mid-April**
- **Goal is to align transition to the alternative TIRS operations concept with the operational implementation of needed modifications within DPAS**

Jim Storey presentation will discuss this in further detail

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U.S. Landsat Archive Overview

(October 1, 2015)

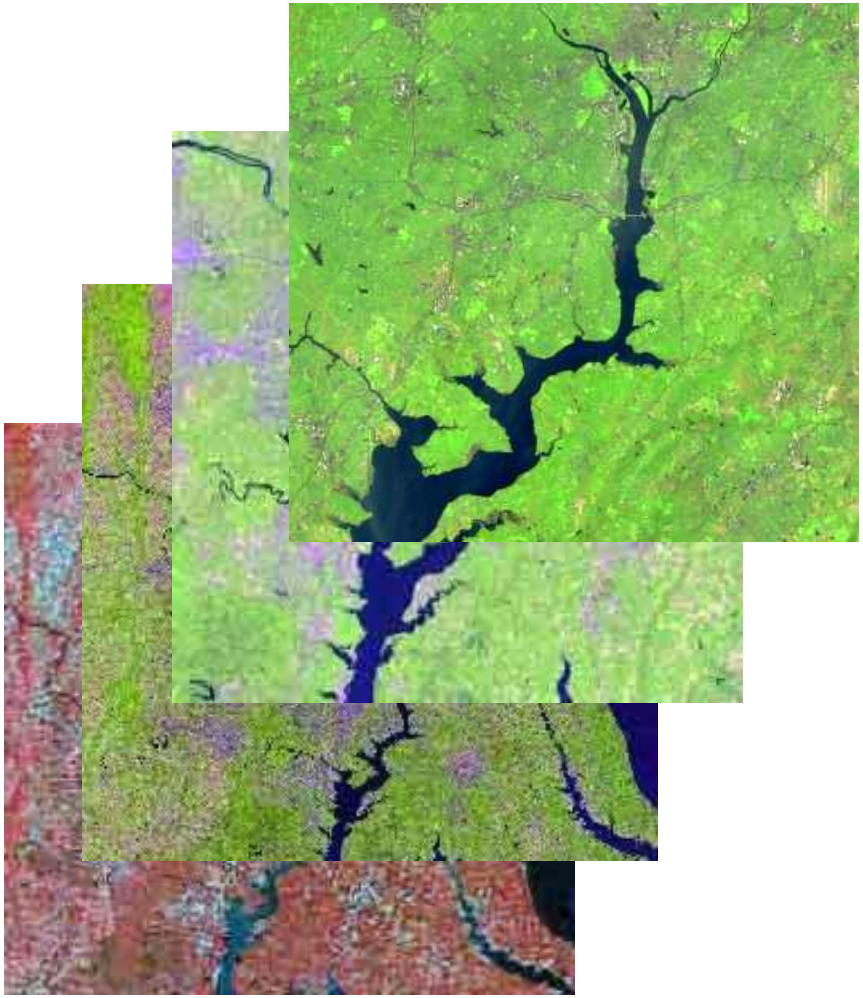
- **OLI-TIRS: Landsat 8**
  - **571,048 scenes**
    - **~ 1,974 TB Raw and L0Ra Data**

      average scene size 1813 MB
- **ETM+: Landsat 7**
  - **2,009,348 scenes**
    - **~ 1,866 TB Raw and L0Ra Data**

      average scene size 487 MB
- **TM: Landsat 4 & Landsat 5**
  - **2,121,570 scenes**
    - **~ 1,064 TB Raw and L0Ra Data**

      average scene size 263 MB
- **MSS: Landsat 1 through 5**
  - **1,300,090 scenes**
    - **~ 79 TB Raw and L0Ra Data**

      average scene size 32 MB
- **Total:**
  - **6,002,056 scenes**
    - **~ 4,983 TB Raw and L0Ra Data**



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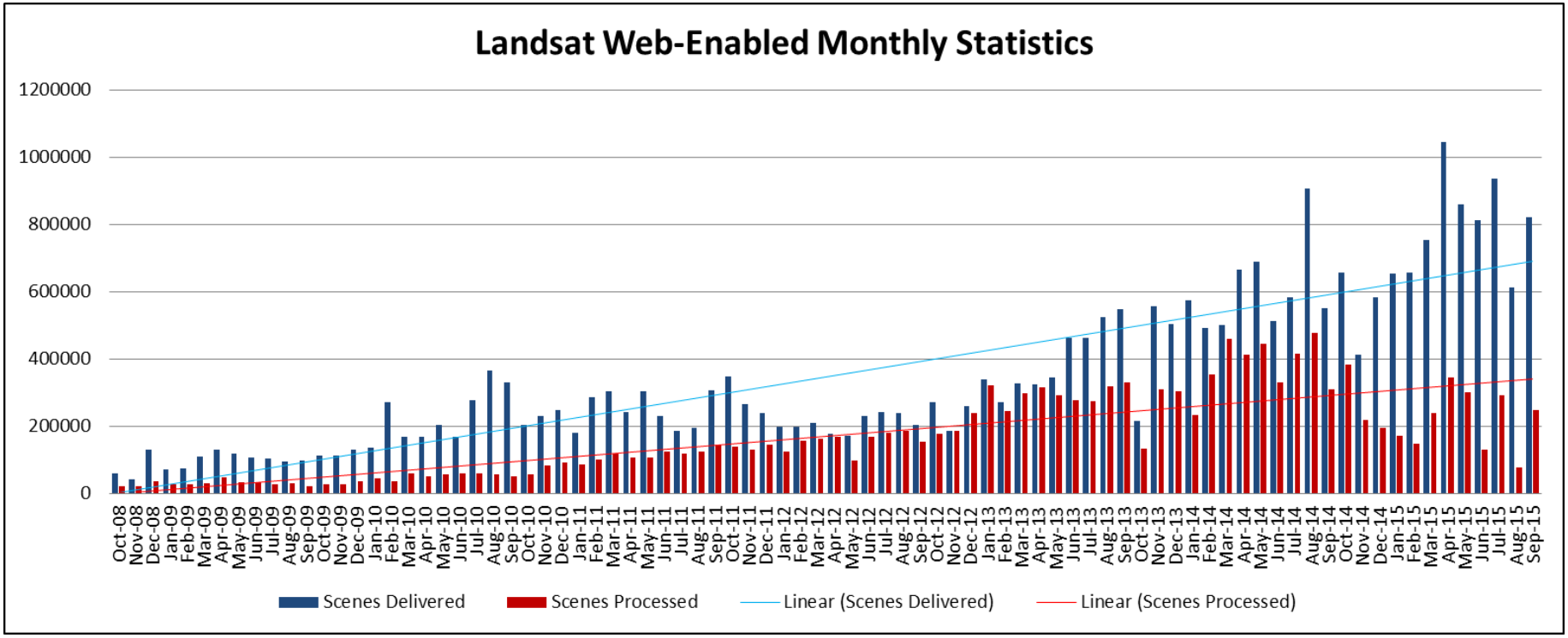
Monthly Downloads/Processed



FY09	FY10	FY11	FY12	FY13	FY14	FY15
Delivered: 1.1M Processed: .4M	Delivered: 2.5M Processed: .6M	Delivered: 2.9M Processed: 1.3M	Delivered: 2.7M Processed: 1.8M	Delivered: 4.3M Processed: 3.3M	Delivered: 6.8M Processed: 4.2M	Delivered: 8.8M Processed: 2.8M

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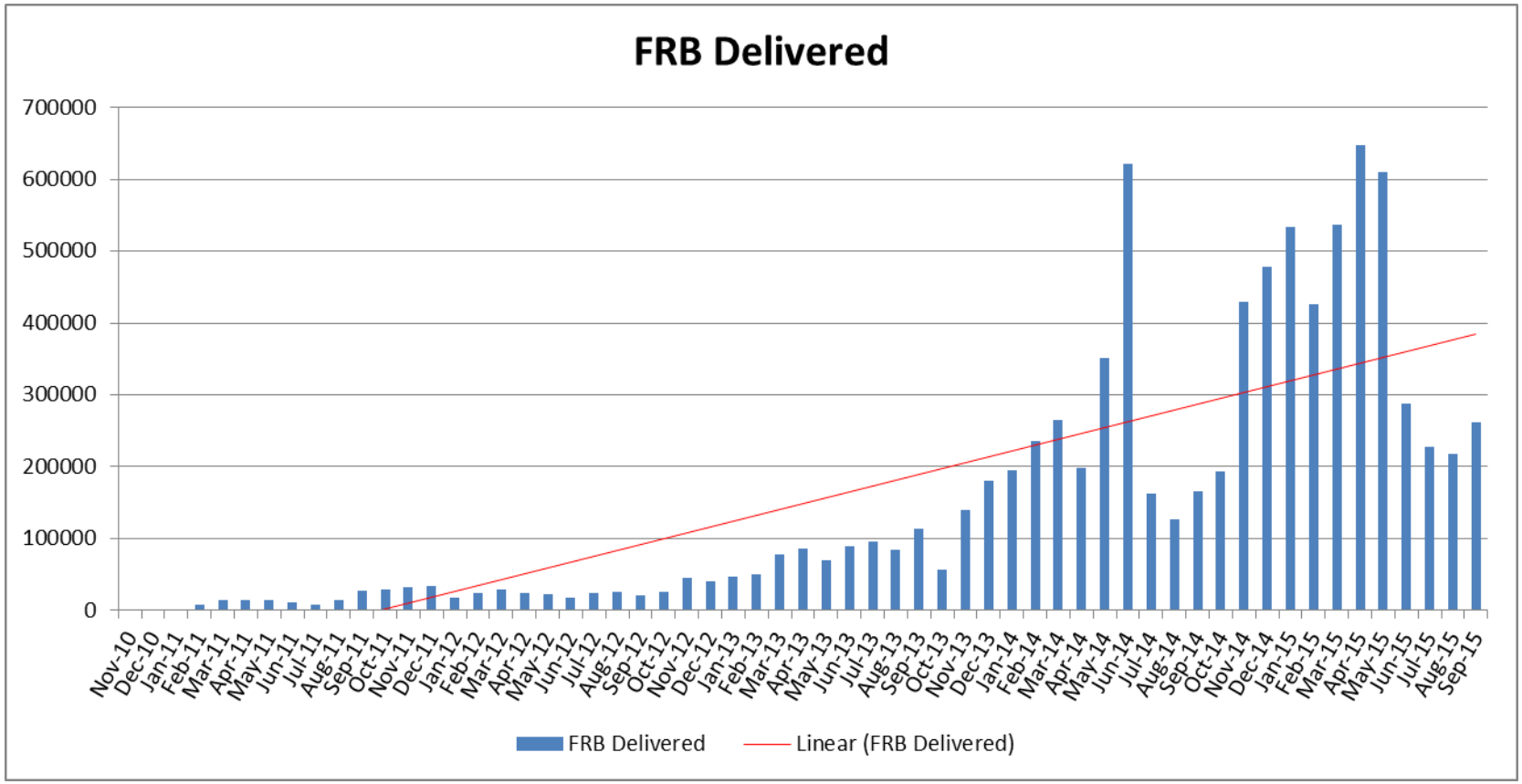
Monthly Full Resolution Browse Downloads



FY11	FY12	FY13	FY14	FY15
Delivered: 112K	Delivered: 301K	Delivered: 823K	Delivered: 2,696K	Delivered: 4,848K

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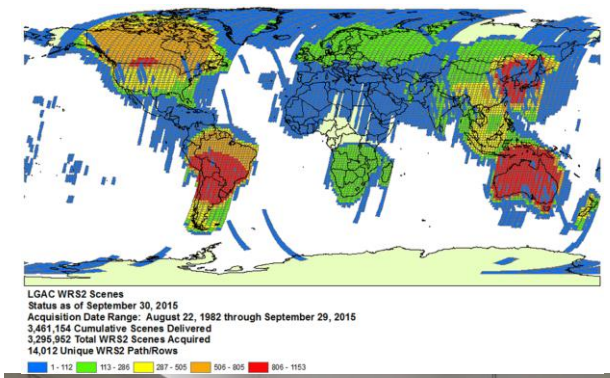
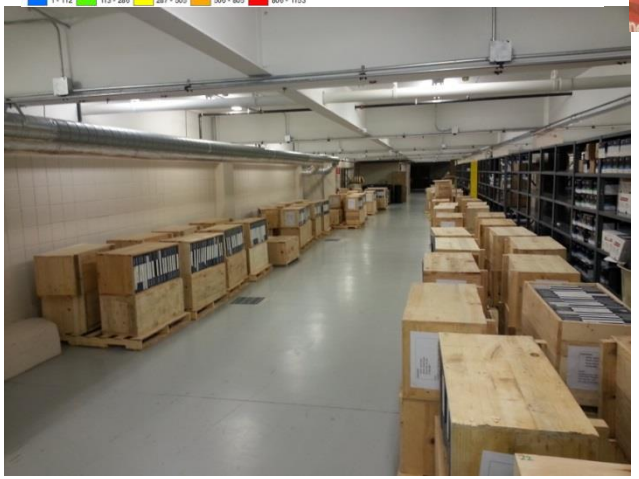
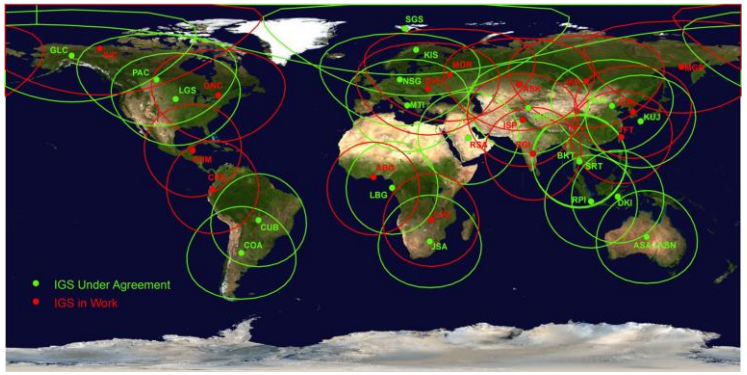
Landsat Global Archive Consolidation Status







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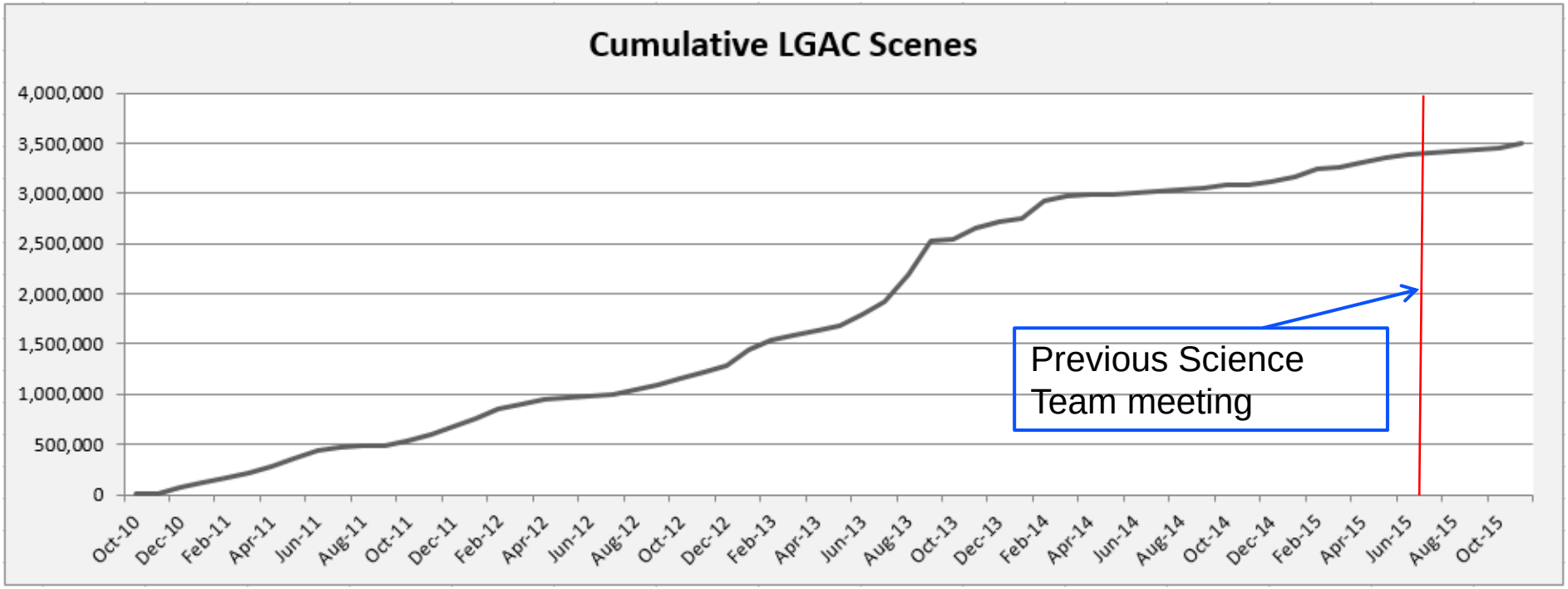
Cumulative LGAC Status



Woodcock Metric: 3,502,611 scenes!

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Recent Major Accomplishments

- **Completed Pakistan (SUPARCO) HDDT Ingest**
  - **Successfully read data off of 2,443 tapes**
  - **Through continuous process improvements and lessons learned, tapes were read in a 21 month period (original projection was 84 months)**
  - **63,564 scenes recovered, with 97% new to the archive**
  - **96% of data with good-to-great scene quality**

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Recent Major Accomplishments

- **Thailand (GISTDA) – Received ~2,000 HDDTs and 3 tape drives to be used for continued LGAC data recovery**
  - **With the completion of the Pakistan HDDTs, Thailand data recovery has begun**

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Recent Major Accomplishments

- **Saudi Arabia (KACST) – Received all TM and MSS data on HDDTs and DLTs**
  - **17,300 HDDTs**
  - **4,045 DLTs**
  - **~250,000 TM scenes**
  - **MSS scene count unknown**

- **Canada (CCMEO) – Received HDDT drive and spare equipment to assist with continuing data recovery effort**
- **India (ISRO) – Received and ingested entire TM archive holdings (~39,000 scenes)**

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LGAC Status

Country (Organization)	Ground Station	% LGAC Delivered	% LGAC Ingested
Argentina (CONAE)	COA	TM	TM
		ETM+	ETM+
Australia (GA-NEO)	ASA	MSS	MSS
		TM	TM
		ETM+	ETM+
Australia (GA-NEO)	HOA	TM	TM
		ETM+	ETM+
Brazil (INPE)	CUB	MSS	MSS
		TM	TM
		ETM+	ETM+
Canada (CCMEO)	GNC	MSS	MSS
		TM	TM
		ETM+	ETM+
Canada (CCMEO)	PAC	MSS	MSS
		TM	TM
		ETM+	ETM+

- **Argentina – LTOs**
  - TM and ETM+ data delivery continues
- **Brazil – HDDTs**
  - USGS to investigate setting up Wideband Video Drive to read tapes
    - ~875 tapes to be sent by Brazil upon sample tape success
    - Primarily consist of MSS data, with very small number of TM intervals also included

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LGAC Status

Country (Organization)	Ground Station	% LGAC Delivered	% LGAC Ingested
China (RADI)	BJC	TM	TM
		ETM+	ETM+
China (RADI)	KHC	TM	TM
Ecuador (IEE)	CPE	TM	TM
Europe (ESA)	FUI	MSS	MSS
		TM	TM
		ETM+	ETM+
Europe (ESA)	KIS	MSS	MSS
		TM	TM
		ETM+	ETM+
Europe (ESA)	MTI	TM	TM
		ETM+	ETM+
Europe (ESA)	MPS	MSS	MSS
		TM	TM
		ETM+	ETM+
Europe (ESA)	NSG	ETM+	ETM+
India (ISRO)	SGI	MSS	MSS
		TM	TM

- **China – Electronic data delivery**
  - TM data delivered in FRED format
- **Ecuador – All data has been received**
  - Addressing several problematic tapes
- **Europe – NAS HDs**
  - Phase I LGAC support consisted of Kiruna (KIS) TM data
    - Issues with missing PCD for ~500,000 TM scenes
    - USGS analysis currently in progress
    - ***Possible that overlap data may be archived at ScanEx in Russia***
  - Phase II LGAC data to consist of all outstanding TM and ETM+ data
    - KIS ETM+, MPS ETM+, and MPS TM data partially delivered so far
    - Additional shipments of TM and ETM+ data in early 2016
    - MSS data to also be delivered in 2016
- **India – USB HDs**
  - All TM data delivered and ingested

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LGAC Status

Country (Organization)	Ground Station	% LGAC Delivered	% LGAC Ingested
Indonesia (LAPAN)	DKI	TM	TM
		ETM+	ETM+
Japan (HIT/HEEIC)	HIJ	ETM+	ETM+
Japan (JAXA/RESTEC)	HAJ	MSS	MSS
		TM	TM
		ETM+	ETM+
Kyrgyzstan (DLR)	BIK	TM	TM
Mongolia (DLR)	ULM	TM	TM
Pakistan (SUPARCO)	ISP	TM	TM
Saudi Arabia (KACST)	RSA	MSS	MSS
		TM	TM
South Africa (SANSA)	JSA	MSS	MSS
		TM	TM
		ETM+	ETM+
Taiwan (CSRSR-NCU)	CLT	TM	TM
Thailand (GISTDA)	BKT	MSS	MSS
		TM	TM
		ETM+	ETM+
US (U of Puerto Rico)	UPR	ETM+	ETM+

- **Indonesia – All data has been received**
  - DCRSi drive parts needed for remaining tapes
- **Pakistan – All HDDTs have been delivered**
  - Tape reading completed in Dec 2015
  - Delivery of additional TM data on LTOs pending
- **Saudi Arabia – All HDDTs and DLTs have been delivered**
  - MSS and TM data
- **South Africa – Migrating from electronic data delivery to USB drives**
- **Thailand – All HDDTs and LTOs have been delivered**
  - MSS, TM, and ETM+ data received
  - Three HDDT drives also delivered

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Remaining Work

- Continue to work to improve ingested data that is not capable of producing L1Ts
- Continue to refine process for reading data off of old media
  - HDDTs
  - DCRSi tapes
- Address parts and equipment concerns for old drives
  - Thailand provided three HDDT drives
  - Canada provided one HDDT drive and spare parts
- Develop MSS data format converters
  - Many different format types
  - Handling of partially processed data

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LGAC Status Summary

GSID	Country	Location	Scenes Ingested Since Sept. 2010														
			MSS					TM					ETM+				
			Actual	Estimated	% Comp	Unique	% Unique	Actual	Estimated	% Comp	Unique	% Unique	Actual	Estimated	% Comp	Unique	% Unique
ASA	Australia	Alice Springs	223,791	224,000	100%	166,582	74%	184,963	185,000	100%	181,058	98%	216,803	216,000	100%	120,866	56%
BIK	Kyrgyzstan	Bishkek						2,340	2,000	100%	1,749	75%					
BJC	China	Beijing						198,795	560,000	35%	189,781	95%	95	47,000	0%	17	18%
BKT	Thailand	Bangkok	0	57,000	0%	0	0%	197,952	185,000	100%	188,209	95%	18,704	26,000	72%	8,268	44%
CLT	Taiwan	Chung Li						11,586	12,000	97%	11,297	98%					
COA	Argentina	Cordoba						103,610	190,000	55%	96,185	93%	116,393	190,000	61%	48,162	41%
CPE	Ecuador	Cotapaxi						25,246	50,000	50%	12,304	49%					
CUB	Brazil	Cuiaba	0	76,000	0%	0	0%	306,656	307,000	100%	263,745	86%	92,164	92,000	100%	52,616	57%
DKI	Indonesia	Parepare						17,017	32,000	53%	16,686	98%	53,192	53,000	100%	23,695	45%
FUI	Italy	Fucino	0	2,000	0%	0	0%	48	567,000	0%	48	100%	0	51,000	0%	0	0%
GNC	Canada	Gatineau						53,019	53,000	100%	14,681	28%	37,955	38,000	100%	9,988	26%
HAJ	Japan	Hatoyama	158,352	158,000	100%	95,208	60%	131,556	132,000	100%	127,107	97%	20,556	21,000	98%	10,667	52%
HIJ	Japan	Hiroshima											39,365	39,000	100%	15,316	39%
HOA	Australia	Hobart						5,812	6,000	97%	5,767	99%	13,110	13,000	100%	5,255	40%
ISP	Pakistan	Islamabad	410	5,000	8%	410	100%	63,564	66,000	85%	61,842	97%					
JSA	South Africa	Hartebeesthoek	0	18,000	0%	0	0%	77,693	119,000	65%	65,682	85%	29,042	29,000	100%	8,621	30%
KHC	China	KaShi						28,053	23,000	100%	26,730	95%					
KIS	Sweden	Kiruna	0	432,000	0%	0	0%	183,508	300,000	61%	180,755	98%	28,592	43,000	66%	17,764	62%
MPS	Spain	Maspalomas	0	154,000	0%	0	0%	16,329	50,000	33%	16,329	100%	7,480	32,000	24%	4,099	55%
MTI	Italy	Matera						2,962	234,000	1%	2,941	99%	27	48,000	0%	3	15%
NSG	Germany	Neustrelitz	5,132	5,000	100%	5,102	99%						12,616	89,000	14%	5,016	40%
PAC	Canada	Prince Albert	414,418	414,000	100%	201,692	49%	369,715	370,000	100%	193,020	52%	100,374	100,000	100%	28,671	29%
RSA	Saudi Arabia	Riyahd	0	5,000	0%	0	0%	1,608	250,000	1%	860	53%					
SGI	India	Shadnagar	0	12,000	0%	0	0%	38,404	39,000	100%	38,054	99%					
ULM	Mongolia	Ulan Bator						565	500	100%	554	100%					
UPR	Puerto Rico	Mayaguez											315	500	63%	118	37%
Totals			**802,103**	**1,562,000**	**51%**	**468,994**	**58%**	**2,021,025**	**3,726,500**	**54%**	**1,695,370**	**84%**	**786,869**	**1,127,500**	**70%**	**359,167**	**46%**

Over 3.6 million scenes ingested!
Approximately 57% complete
Approximately 69% of scenes are new to the archive!

- **Includes partial scenes**
- **Green = Completed**

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LGAC Notional Timeline – TM

International Cooperator			TM					Notes / Notional Timeline (highlights are change from Summer 2015 LST meeting)
GSID	Country	Location	Actual	Estimate	% Comp.	Unique	% Unique	
BJC	China	Beijing	198,795	560,000	35%	189,781	95%	Anticipate completion of TM by end of ~~2016~~ 2017
BKT	Thailand	Bangkok	197,952	185,000	107%	188,209	95%	Anticipate completion of TM data on HDDTs ~~could take multiple years~~ by end of 2018
COA	Argentina	Cordoba	103,610	190,000	55%	96,185	93%	Anticipate completion of TM and ETM+ by ~~mid-2016~~ end of 2016
CPE	Ecuador	Cotapaxi	25,246	50,000	50%	12,304	49%	Being worked; no anticipated date at this time
DKI	Indonesia	Parepare	17,017	32,000	53%	16,686	98%	Completion of TM data on DCRSi tapes could take some time due to mold problems on the tapes
FUI	Italy	Fucino	48	567,000	0%	48	100%	Anticipate completion of 1982-1986 and 2000-2001 TM data by ~~late 2015~~ end of 2016; TM data from 1987-1999 have poor PCD - decision on how to handle this data is pending
ISP	Pakistan	Islamabad	63,564	60,000	106%	61,842	97%	Completion of TM data on LTOs unknown at this time
JSA	South Africa	Hartebeesthoek	77,693	119,000	65%	65,682	85%	Anticipate completion of TM data by end of ~~2015~~ 2016
KHC	China	Kashi	28,053	23,000	122%	26,730	95%	Anticipate completion of TM data by ~~end of 2015~~ mid-2016
KIS	Sweden	Kiruna	183,508	300,000	61%	180,755	98%	Outstanding TM data contains poor PCD (~40% of TM data holdings) - decision on how to handle data pending (1991-1996)
MPS	Spain	Maspalomas	16,329	50,000	33%	16,315	100%	Anticipate delivery by end of ~~2015~~ 2016
MTI	Italy	Matera	2,962	234,000	1%	2,941	99%	Anticipate completion of TM and ETM+ data by end of ~~2015~~ 2016
RSA	Saudi Arabia	Riyahd	1,608	250,000	1%	860	53%	Completion of TM data on HDDTs could take multiple years
Totals			916,385	2,620,000	35%	858,338	94%	

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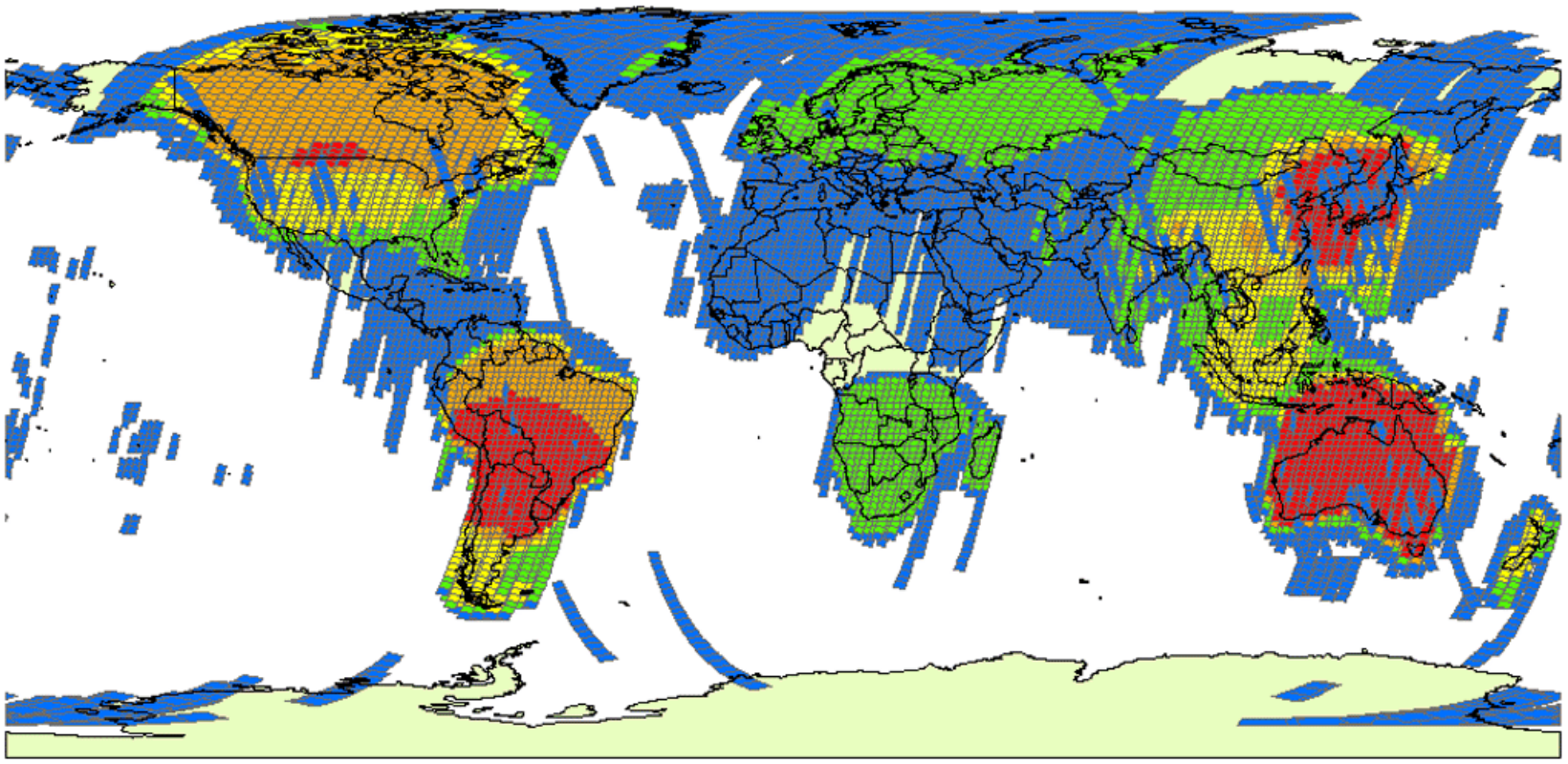
LGAC WRS-2



LGAC WRS2 Scenes
Status as of September 30, 2015
Acquisition Date Range: August 22, 1982 through September 29, 2015
3,461,154 Cumulative Scenes Delivered
3,295,952 Total WRS2 Scenes Acquired
14,012 Unique WRS2 Path/Rows

1 - 112 | 113 - 286 | 287 - 505 | 506 - 805 | 806 - 1153

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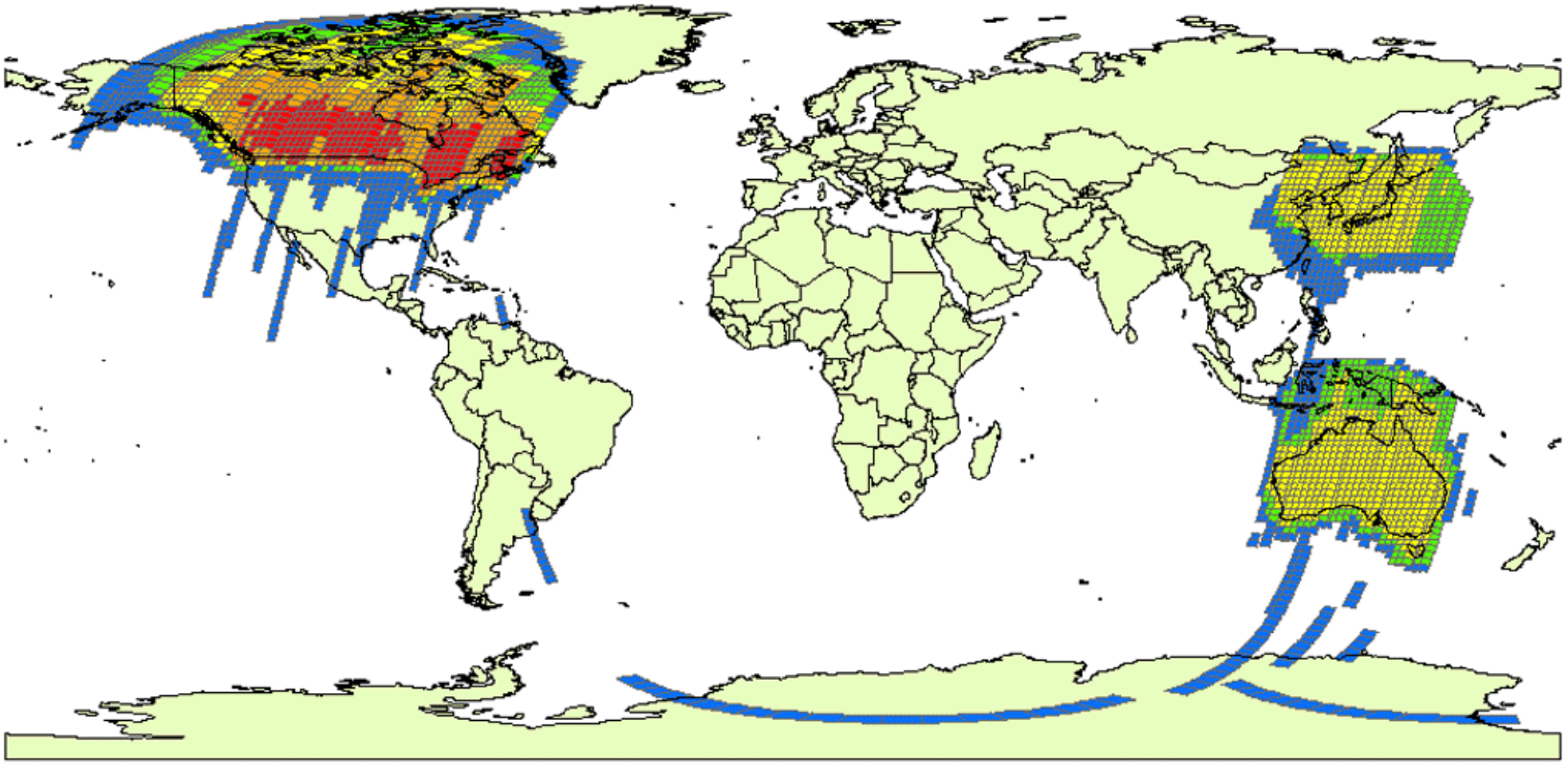
LGAC WRS-1



LGAC WRS1 Scenes
Status as of September 30, 2015
Acquisition Date Range: July 26, 1972 through March 31, 1983
3,461,154 Cumulative Scenes Delivered
165,202 Total WRS1 Scenes Acquired
3,521 Unique WRS1 Path/Rows

1 - 20 | 21 - 44 | 45 - 67 | 68 - 94 | 95 - 135

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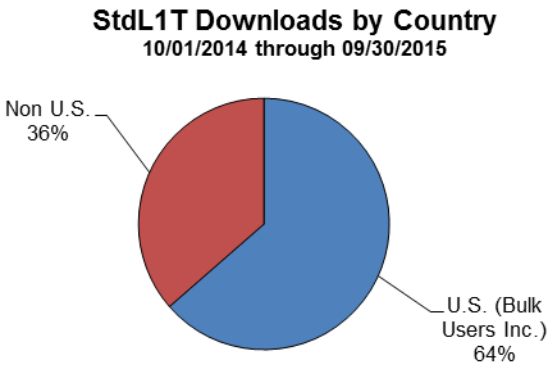
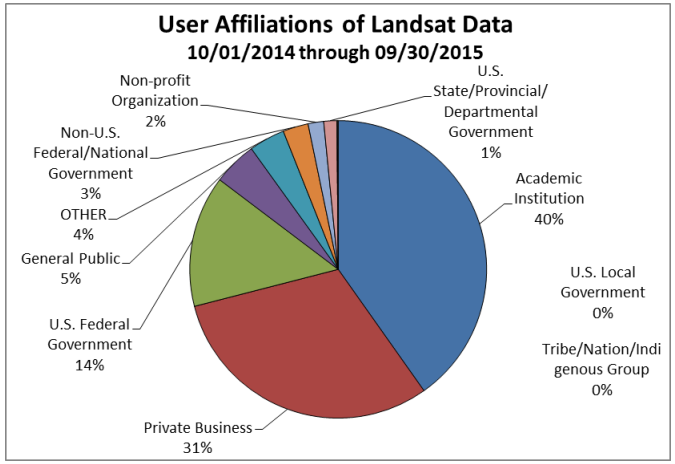
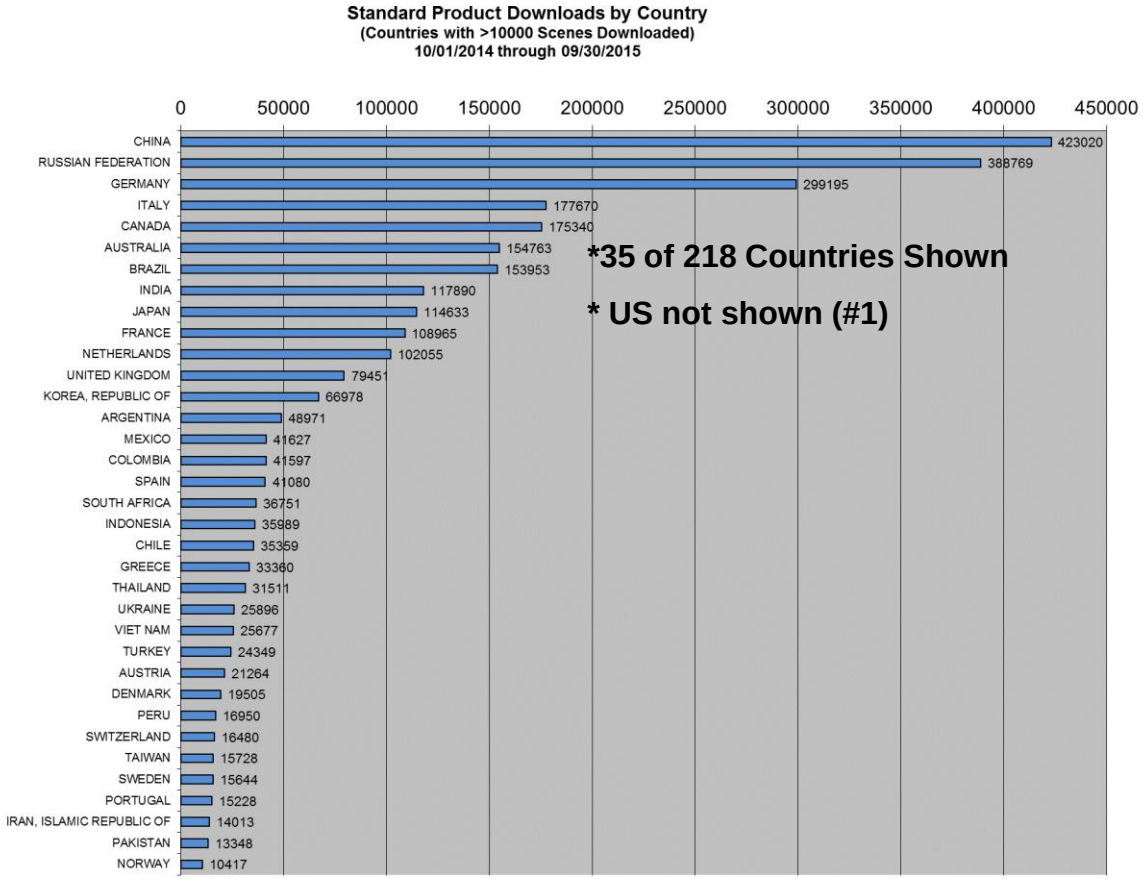
Reference / Backup Slides

Web-enabled Customer Demographics







***35 of 218 Countries Shown**

*** US not shown (#1)**

*** Stats 10/1/14 through 9/30/15**

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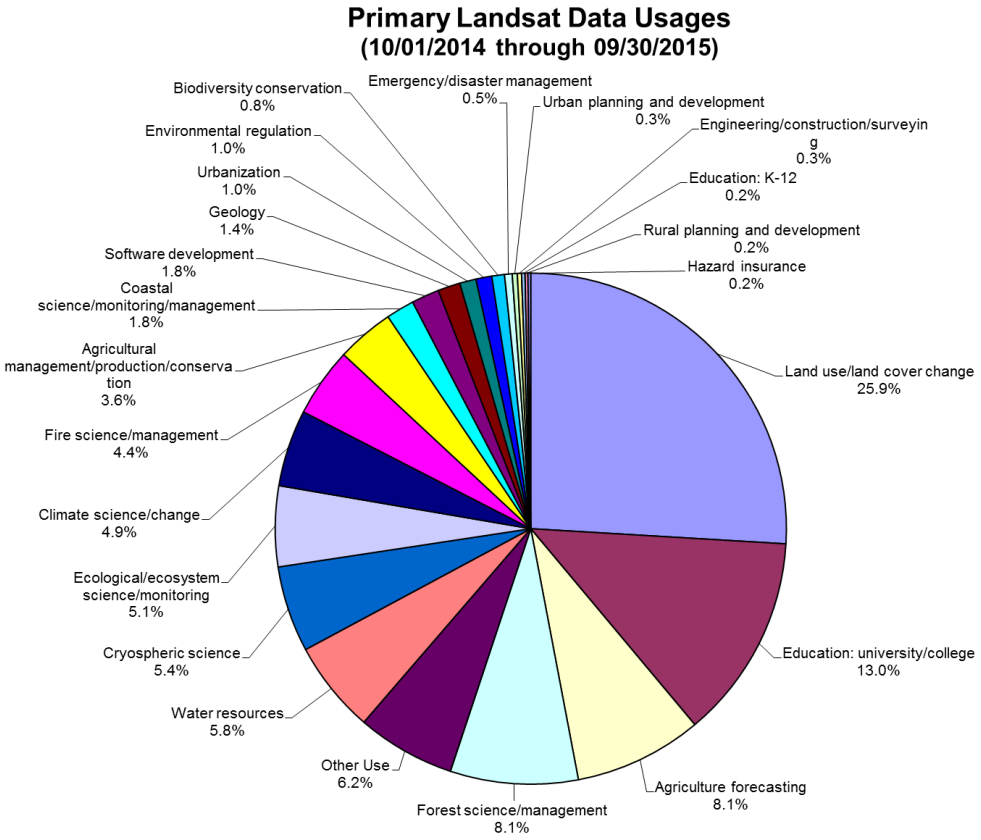
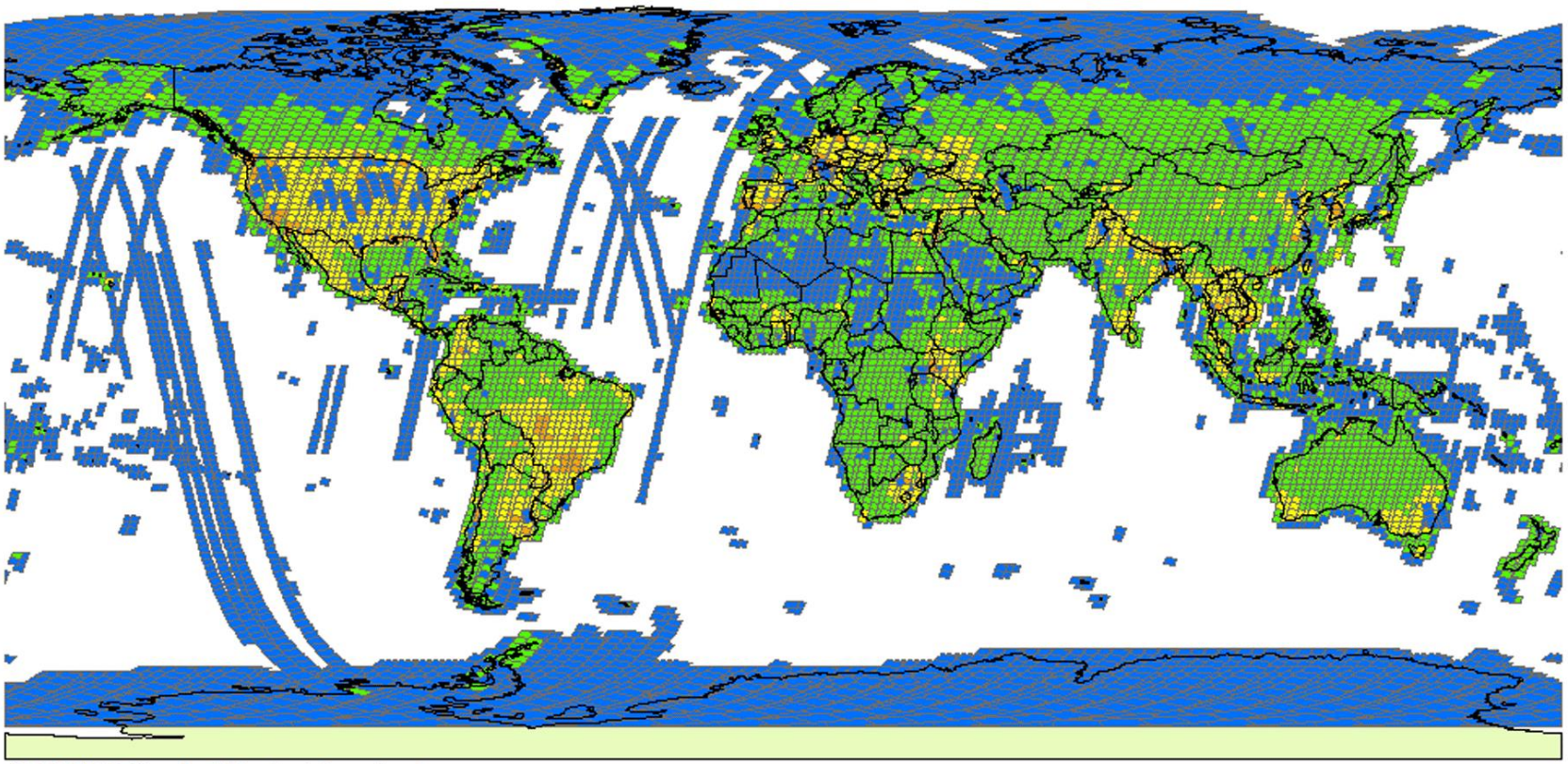
User Reported Primary Use of Landsat (Oct 1, 2014 – Sep 30, 2015)



USGS

OLI/TIRS Downloads

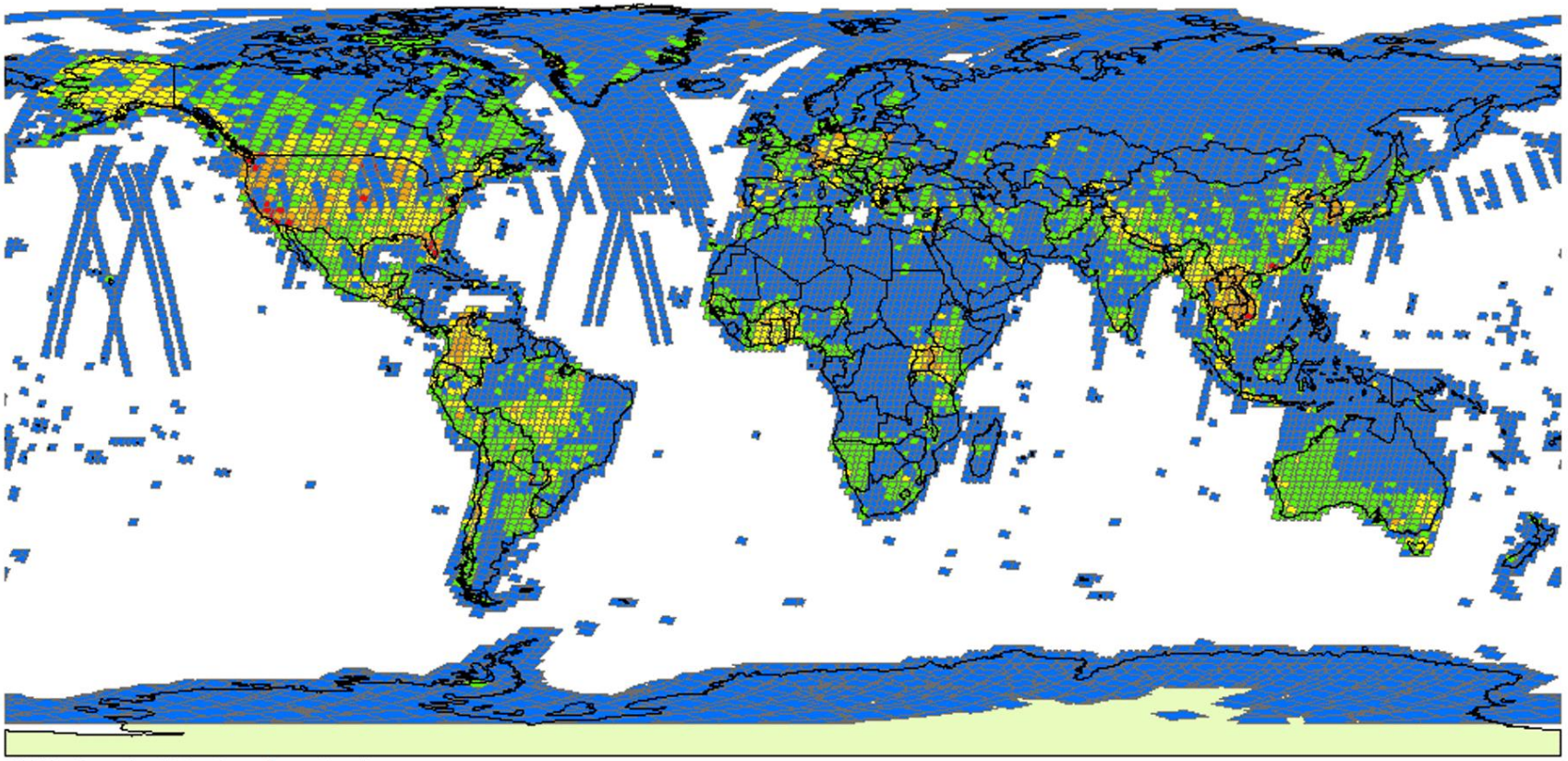


OLI & TIRS Standard Product Downloads
via User Interface
October 01, 2014 through September 30, 2015
7,145,326 Total Cumulative Scenes Delivered
2,656,241 Total OLI & TIRS Scenes Delivered
18,954 Unique OLI & TIRS Locations

1 - 128 | 129 - 367 | 368 - 806 | 807 - 2936 | 2937 - 39545

USGS

ETM+ Downloads

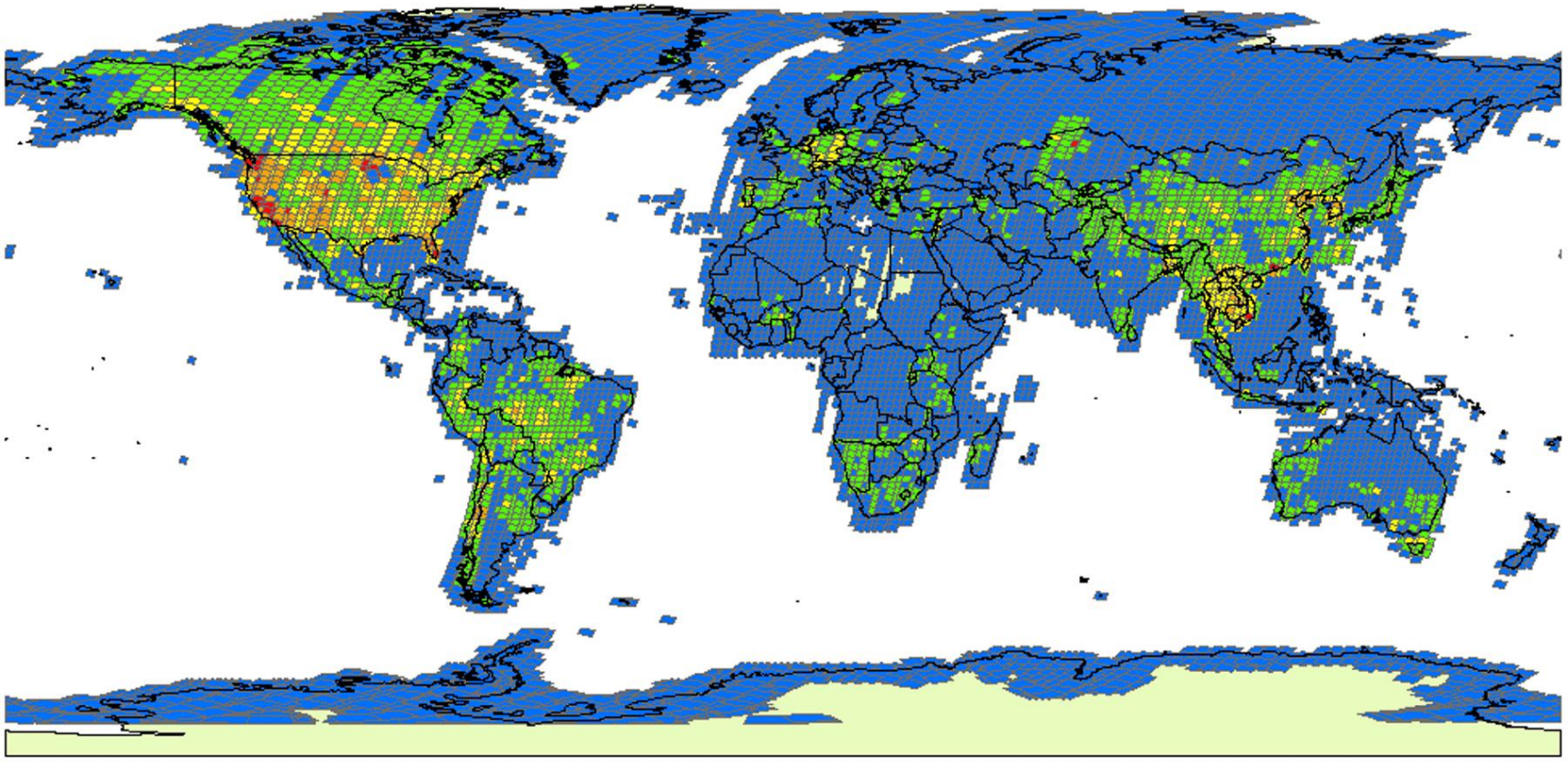


ETM+ Standard Product Downloads
via User Interface
October 01, 2014 through September 30, 2015
7,145,326 Total Cumulative Scenes Delivered
1,999,066 Total ETM+ Scenes Delivered
15,957 Unique ETM+ Locations

1 - 144 | 145 - 438 | 439 - 936 | 937 - 1955 | 1956 - 4435

USGS

TM Downloads

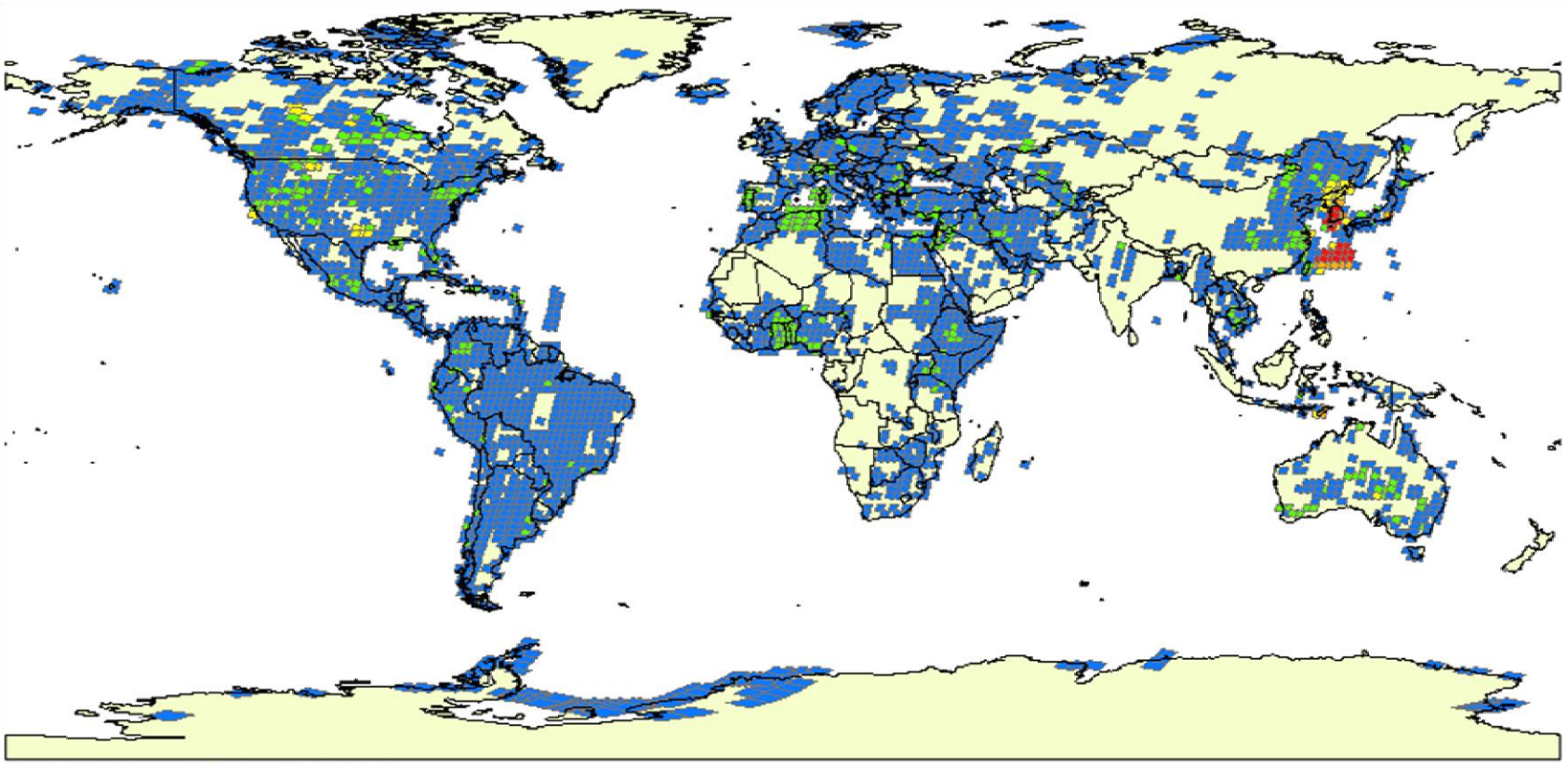


TM Standard Product Downloads
via User Interface
October 01, 2014 through September 30, 2015
7,145,326 Total Cumulative Scenes Delivered
1,975,390 Total TM Scenes Delivered
12,098 Unique TM Locations

1 - 176 | 177 - 606 | 607 - 1419 | 1420 - 2995 | 2996 - 7768

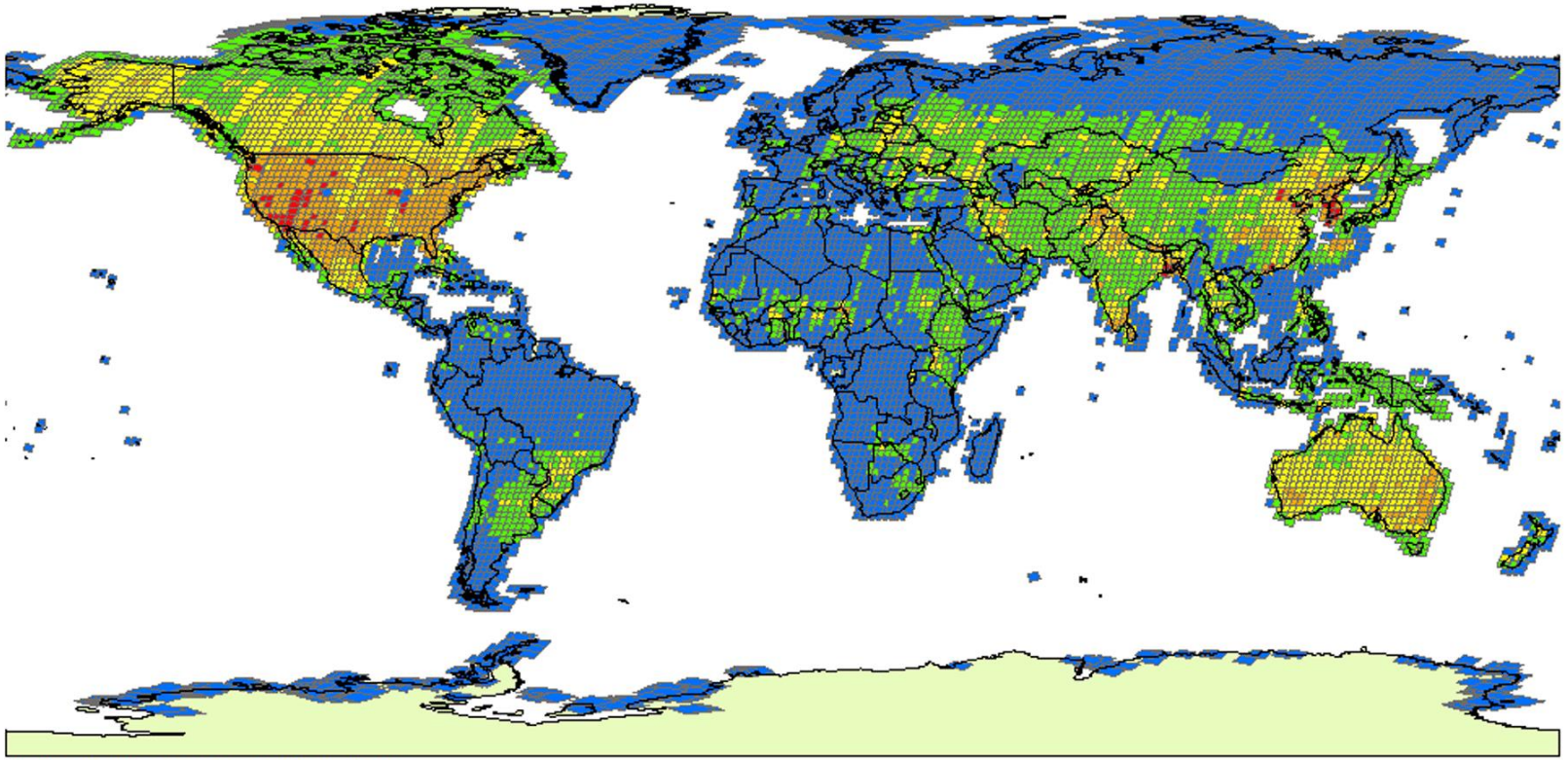
USGS

Landsat 4-5 MSS Downloads



USGS

Landsat 1-3 MSS Downloads



L1-3 MSS Standard Product Downloads
via User Interface
October 01, 2014 through September 30, 2015
7,145,326 Total Cumulative Scenes Delivered
514,629 Total MSS Scenes Delivered
458,778 Total L1-3 MSS Scenes Delivered
10,168 Unique L1-3 MSS Locations

1 - 31 | 32 - 72 | 73 - 132 | 133 - 237 | 238 - 856

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Mission-Limiting Factors

- **Component Anomalies: Mission status that invokes consideration of decommissioning**
  - **End of Science Mission: A critical failure of either the ETM+ or supporting bus subsystem**
  - **Immanent failure of critical sub-system component capability considered necessary to execute the decommission plan**
    - **Loss of critical subsystem redundancy may not be an exit trigger and would be evaluated on a case-by-case basis**
    - **Examples include ACS gyro or C&DH S-band transponder**
- **Fuel Reserves**
  - **Sufficient fuel must be maintained to meet mission decommissioning requirements**
    - **The satellite is lowered below the operational orbit of the 705km constellation**

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TIRS Encoder On-Orbit Testing

- **A test of mode 0 on B-side (with the encoder powered) commenced on October 29 and completed November 2, 2015**

- **Additional tests were conducted as encoder current continued to increase - tests mimic the mode 0 operational contingency plan and served as a rehearsal for mode 0 operations.**

  - **On 11/13 turned on the encoder, performed a normal instrument calibration, along with a pendulum park sequence, and encoder power off**
  - **Allowed the SSM to drift until 11/26**
    - **Cal/Val generated an SSM drift profile via analyzing TIRS imagery**
  - **On 11/26 powered on the encoder, performed lunar calibration, along with pendulum park sequence, and encoder power off**
    - **Some "healing" of Encoder B-side current observed (Baseline ~ 80.5 mA)**
  - **Allowed the SSM to drift until 12/11**
    - **Cal/Val generated a second SSM drift profile via analyzing TIRS imagery**
  - **On 12/11 turned on encoder and operated on Encoder B-side in Mode 4 (SSM fixed to nadir) with calibrations every two weeks**
    - **Assessed potential correlation between rise in baseline current and frequency of calibrations**
  - **On 12/17 performed pendulum park and turned Encoder off (Mode 0) following continued rise in baseline Encoder current**

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